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PRODUCT EVALUATION OF ZEBRA MUSSEL CONTROL METHODS FOR SMALL VOLUME WATER USERS

RAC PROJECT NO. 657C

Ontario
Environment
Environnement

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PRODUCT EVALUATION OF ZEBRA MUSSEL CONTROL METHODS FOR SMALL VOLUME WATER USERS

RAC PROJECT NO. 657C

PREPARED FOR THE MINISTRY OF ENVIRONMENT AND ENERGY AND THE MINISTRY OF NATURAL RESOURCES BY:
AQUATIC SCIENCES INC.

JULY 1993
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Ministry of Environment and Energy and the Ministry of Natural Resources

Ministry of Environment and Energy
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Aquatic Sciences Inc.
Acknowledgement and Disclaimer

This study was completed under funding and direction of the Ontario Ministry of Environment and Energy and the Ontario Ministry of Natural Resources. The views and ideas expressed in this report are based on the criteria for testing and study design as approved by these agencies. This report was prepared as a collaborative effort by Aquatic Sciences Inc., Ministry of Environment and Energy and Ministry of Natural Resources personnel all of whom contributed to its completion in the present format. The results do not reflect anything other than an assessment of single products in a single study as designed by the aforementioned group. Aquatic Sciences does not endorse or reject the use of any single product as tested in this study.

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RESEARCH OF ZEBRA MUSSEL CONTROL METHODS FOR SMALL VOLUME WATER USERS

M9282

ABSTRACT

A study to determine the efficacy and evaluate overall performance of a number of products designed to eliminate or limit zebra mussel (*Driessena polymorpha*) infestation of small volume water intake systems was undertaken during the summer of 1992. Ten products, most of which are already commercially available, were chosen for testing by the Ministry of the Environment and Energy and Ministry of Natural Resources' personnel. As stipulated by this group, all products submitted for testing had to be non-chemical in nature. Six of the products were filters (cartridge or multimedia) while the remaining four products included three magnetic based products and one electrostatic device. The products were installed on pilot scale pumping systems which operated for approximately 11 weeks (August 10 - October 19) in waters heavily infested by zebra mussels. Larval mussels entering each system were monitored throughout the study. Upon termination of the trials the products were removed and associated piping and tanks from each system were visually inspected and microscopically examined for zebra mussel colonization. It was evident after analysis that although the filter products were sometimes either difficult to install or maintain, they proved to be the most efficient at removing veligers (larval stage zebra mussels) from the incoming water and thereby preventing down stream settlement within the system. The hydrodynamics devices proved to be effective, preventing growth in the intake pipe, which was part of a recirculating system necessary for this installation, however, downstream surfaces were not protected. The electrostatic and remaining magnetic device had very limited effect on mussel settlement.

1.0) INTRODUCTION

Aquatic Sciences Incorporated of St. Catharines, Ontario was contracted by the Ontario Ministry of the Environment and Energy (MOEE) and Ontario Ministry of Natural Resources (MNR) to perform product testing of non-chemical devices currently available for protecting small volume water systems from zebra mussel infestation. The zebra mussel has already been sighted in Ontario's inland water systems including the Kawartha and Muskoka lakes. Many of the small volume water users (hereafter referred to as SVWU), for example cottages and resorts on these systems, have expressed fear and concern over potential problems these mussels may cause, should numbers increase. In response to a perceived need, the Ministries began requesting information from manufacturers in the private sector about non-chemical products which could be installed on small volume water systems for the purpose of preventing mussel growth within the system. From the approximately 100 responses, 10 products were chosen for testing. These products in turn were handed over to Aquatic Sciences Inc. (ASI) by the manufacturers along with specific installation instructions, on July 9, 1992.

The products chosen for testing included:

A. Alex Milne Associates Ltd. (2 products)
    1. Zebra Guard Sand Cottage Filter
    2. Zebra Guard Cartridge Filter
B. D.R. Lowther Consulting
    3. Cartridge Filter (replaces footvalve)
C. Myco Industries (AIM Trading Co.)
    4. Cartridge Filter (installed after footvalve)
D. ISP Canada Inc.
    5. Surface Cartridge Filter (installed on pump discharge)
E. Harcourt Technologies
    6. Magnetic Units (installed on intake pipe)
F. York Energy Conservation
    7. Ion Stick
G. Modern Concepts/WHW Res. Management (2 products)
    8. Hydrodynamics Unit 6JR
    9. Hydrodynamics Unit 6JR-Z
H. Ron Whitcombe
    10. Surface Sand Filter

Prior to the installation of the products, a telephone survey of SVWU's on the Kawartha and Muskoka lakes was undertaken by ASI personnel. The intent of the survey was to determine general configuration of the average SVWU system. The following information was compiled:

- water source
- pump size and type
- diameter and length of intake pipe
- depth of foot valve
- intake pipe material
- type of water treatment (if any)
- system type (continuous or demand)

This information was in turn used to design a pilot scale test system which would accurately mimic the average SVWU system. A copy of the questionnaire used during the phone survey is included in the report. Approximately 50 cottage and resort owners were contacted during the survey. The survey results indicated that the average SVWU's system consisted of a 1/3 H.P. jet pump, 20 - 30 feet of 1 1/2" black polyethylene intake line and a brass footvalve, suspended off of the bottom in approximately 10 - 20 feet of water. A pressurized holding tank was also common, usually located close to the building.

It should be noted that many of the people contacted were very well informed about the zebra mussel issue and the majority expressed relief and gratitude that this type of research had been initiated.

2.0) METHODOLOGY

2.1) Study Site

The site chosen for this testing was an established zebra mussel research facility operated by Aquatic Sciences Inc. The facility is located on Lake Moodie only minutes from ASI's offices in the Niagara Region (Figure 1). This site was chosen for this project because of it's immediate proximity to a water source already infested with zebra mussels and the fact that a fully serviced research trailer was already on site. Lake Moodie draws water from the Welland Canal which in turn is fed by Lake Erie. Previous years monitoring by ASI indicated that it was an excellent source of veliger rich water during the summer months. The site's proximity to ASI offices allowed technicians to monitor operation of the equipment on a daily basis throughout most of the project.

2.2) Experimental Design

Information obtained during the telephone survey was used to design a pilot scale SVWU system, Each system consisted of a 1/3 horsepower jet pump, approximately 20 feet of 1 1/2" black polyethylene intake pipe, a brass footvalve, and a holding tank on the discharge of the pump which contained PVC setting plates. These plates were checked periodically for mussel growth. Cinder

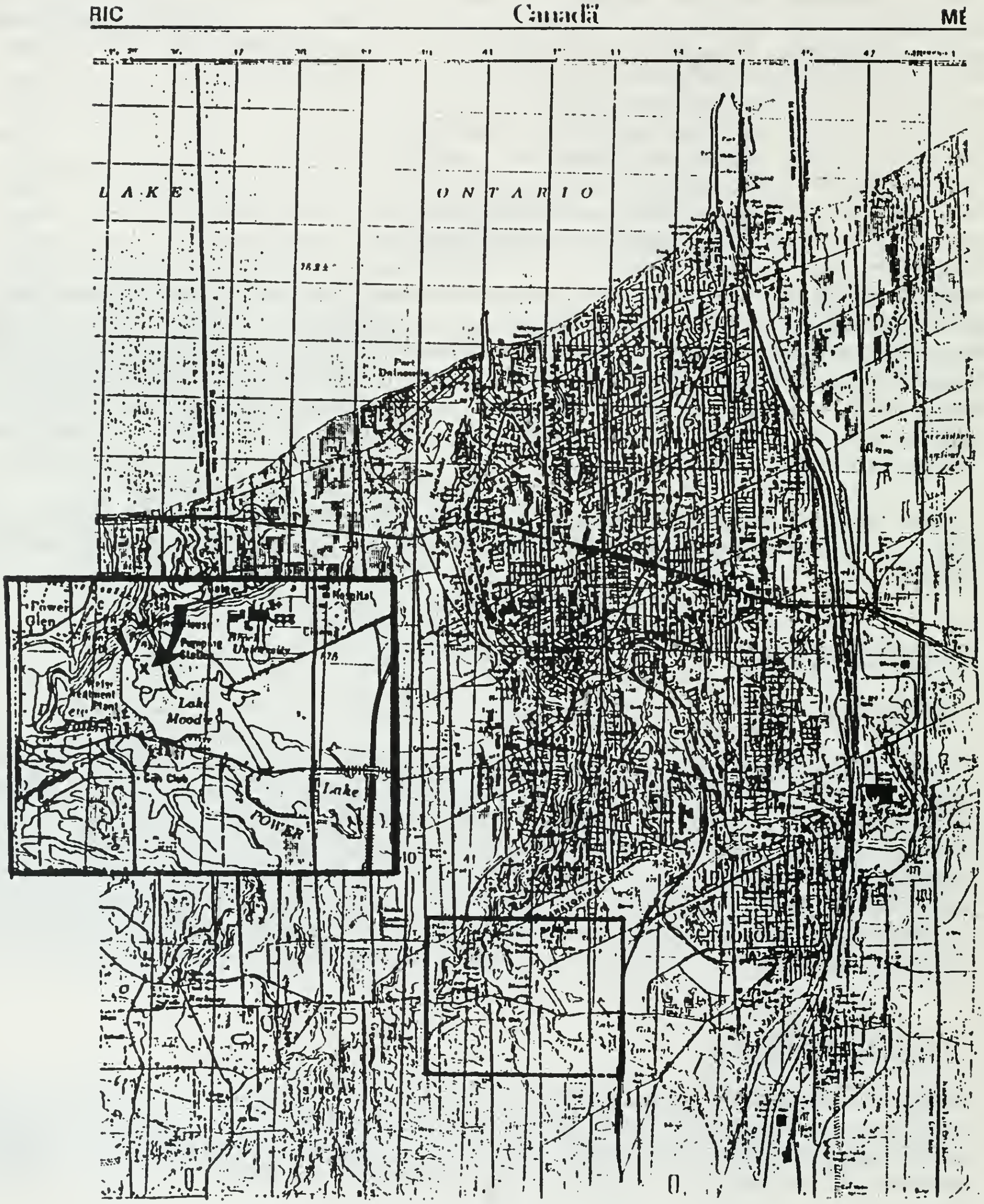
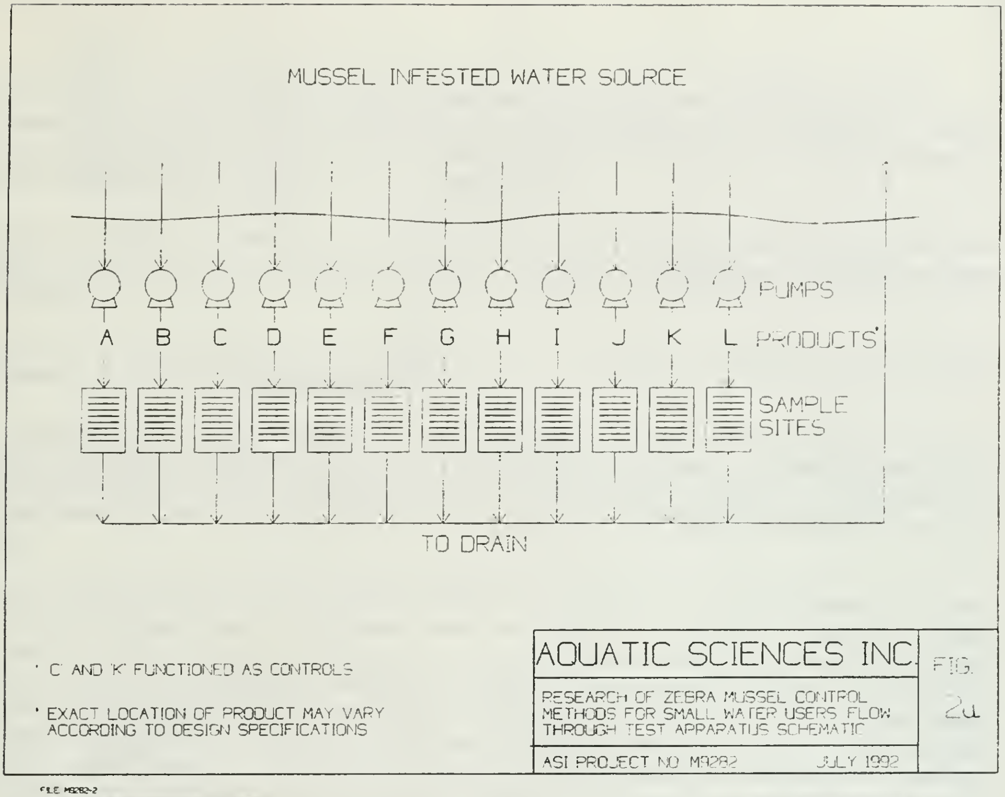


FIGURE 1. Map of research site, "x" marks exact location.



' 'C' AND 'K' FUNCTIONED AS CONTROLS

' EXACT LOCATION OF PRODUCT MAY VARY ACCORDING TO DESIGN SPECIFICATIONS

AQUATIC SCIENCES INC.

RESEARCH OF ZEBRA MUSSEL CONTROL METHODS FOR SMALL WATER USERS FLOW THROUGH TEST APPARATUS SCHEMATIC

ASI PROJECT NO M9282 JULY 1992

FIG. 2a

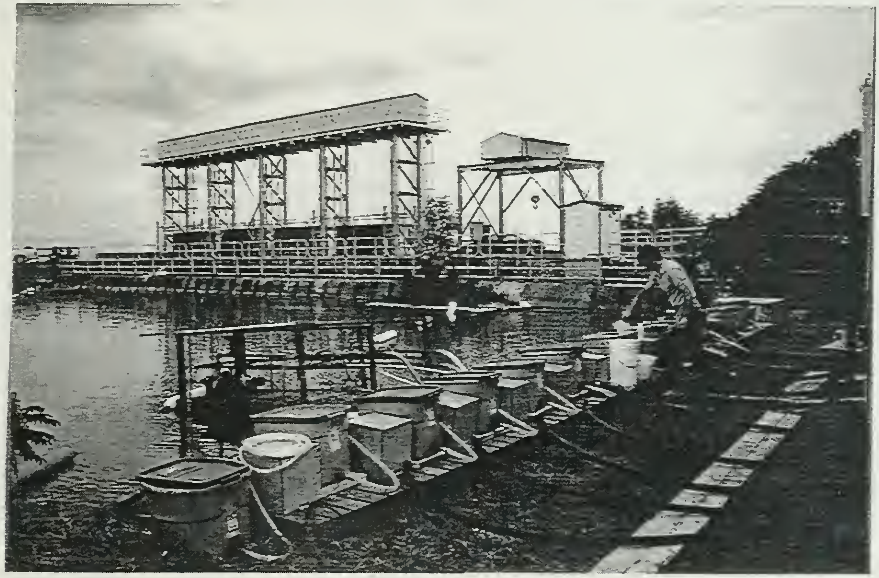


FIGURE 2b. Pumping systems at research site

blocks were used to keep the foot valves off lake bottom. Twelve systems were fabricated, one to accommodate each of the ten products and two control systems which were left unprotected (Figure 2a, b). Each of the 10 systems for product testing were identical except for slight variations to accommodate specific product installation requirements.

All of the products were installed on August 8, 1992 by ASI divers. Manufacturers were consulted prior to installation and were invited to the site to verify that the products were installed to their satisfaction.

The control systems were located at opposite ends of the product test site in the event that differences in veliger densities existed within the site.

It was discovered, during the telephone survey, that the majority of SVWU systems operated on a demand only basis. That is, the pump only engaged when there was a demand for water in the building. To simulate this type of operation, all of the pumping systems were operated from a set of electrical timers which could be programmed to engage and disengage the pumps at specified times.

Since 12 systems were in operation it was difficult to program frequent on/off cycles due to power consumption requirements. The systems were therefore put in groups of three, each group operating at different times. The timers were set up such that each group of three pumps operated for a two hour period three times daily for a total of six hours without overlap. As previously mentioned the pumps discharged into 70 litre holding tanks which contained PVC substrate plates (approximately 234 cm^2), (Figure 3). Each holding tank was fitted with a stand pipe drain which kept the tanks filled with water between pump cycles. The tank overflow drained back to the lake through 1" clear tubing. On system start up, flow through all systems ranged between 40 and 50 litres per minute.

2.3) Monitoring

Full time research technicians carried out monitoring on a daily basis throughout most of the duration of the project. This proved to be invaluable, resulting in the accumulation of a significant amount of data for interpretation and also ensured that the systems were maintained operating, with few exceptions, trouble-free.

Daily monitoring of the pumping systems included the collection of 20 litre grab samples from each of the holding tanks while the pumps were operating, (Figure 4). Systems were allowed to flush completely prior to sample collection. This allowed an estimation of the number or density of veligers which were entering each system relative to the controls.

These 20 litre samples were concentrated to approximately 2 mls through a 53 micron mesh. This 2 ml sample was then examined under 80x magnification and a veliger density (number per cubic meter) calculated for each system.

Observations on condition (live or dead) of veligers and general water quality (i.e. water clarity, algae) including temperature inside holding tanks were also recorded daily. Actual turbidity measurements were obtained from a nearby water filtration plant which gives an indication of relative turbidity at the site. Flow through the holding tanks was checked periodically. Samples were collected and analyzed from settling plates on several occasions to determine if mussel colonization had begun in any of the holding tanks. One plate was removed from each tank and all material cleaned from the surface (234 cm^2) for examination under 80x magnification.

An important aspect of this study was the daily monitoring of the products themselves in terms of the level of maintenance required for effective operation. Notes were taken regarding the products general performance, cleaning and/or maintenance frequency. The level of effort required to install each product was also considered when assessing overall performance. Generally, for this study, it was considered beneficial if two lay adults could easily install the product.

The field testing portion of this project was terminated when veliger densities in the water source fell below 1 per litre and water temperatures were low enough that the majority of reproduction had ceased for the season.

All products were removed on October 23, 1992, by ASI divers. Visual inspections of all exposed surfaces were completed by the research technicians on site. The intake lines were then removed and drained. Four 15 cm sections of intake pipe, were then cut from the total length of the line, equidistant from each other, between the foot valve and the water line. The outside portions of these pipe sections were cleaned of all organic growth. The sections were then labelled and preserved in 25% ethanol for microscopic analysis at a later date. The sections of pipe not used for detailed analysis were visually inspected for juvenile mussel growth on the inside surfaces.

In addition to the pipe samples, the remaining P.V.C. settling plates in each holding tank were scraped and the samples preserved in the same manner for microscopic analysis. The inside surfaces of the holding tanks were also scraped (approx. 2,000 cm^2) and analyzed for mussel growth. After analysis, density calculations were made for each of the three surfaces sampled. This was accomplished by taking the mean of the number of mussels found and dividing this by the total area sampled, producing a $\#/cm^2$.

3.0) RESULTS

The results will be described on a product by product basis. The densities of veligers and the settlement of juvenile mussels on surfaces of the test systems will be compared to the unprotected control systems. Product installation and maintenance results will also be included. Veliger densities reported in this section represent those which have infiltrated the system and are given in terms of $\#/m^3$. Densities of settled juvenile mussels are given in terms of $\#/cm^2$ from each of the three surfaces that were sampled.

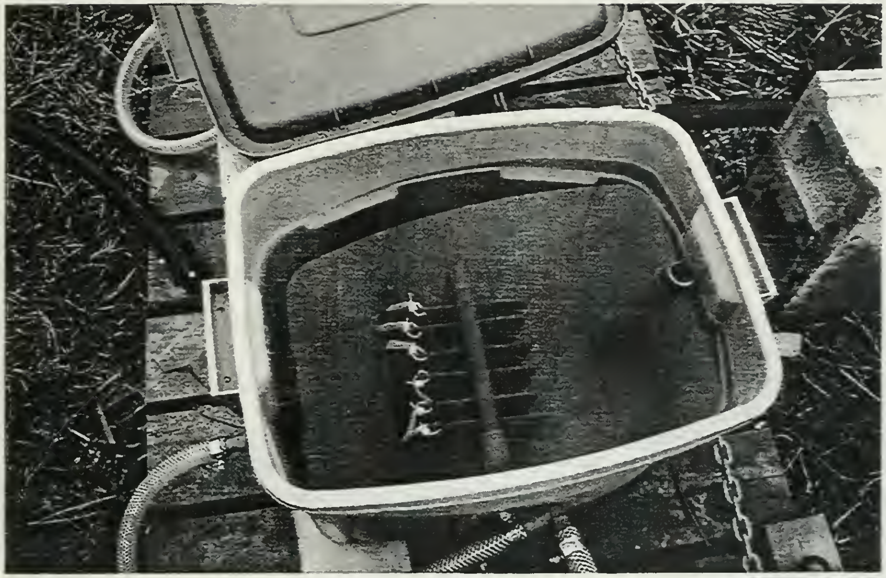


FIGURE 3. Holding tank with substrate rack

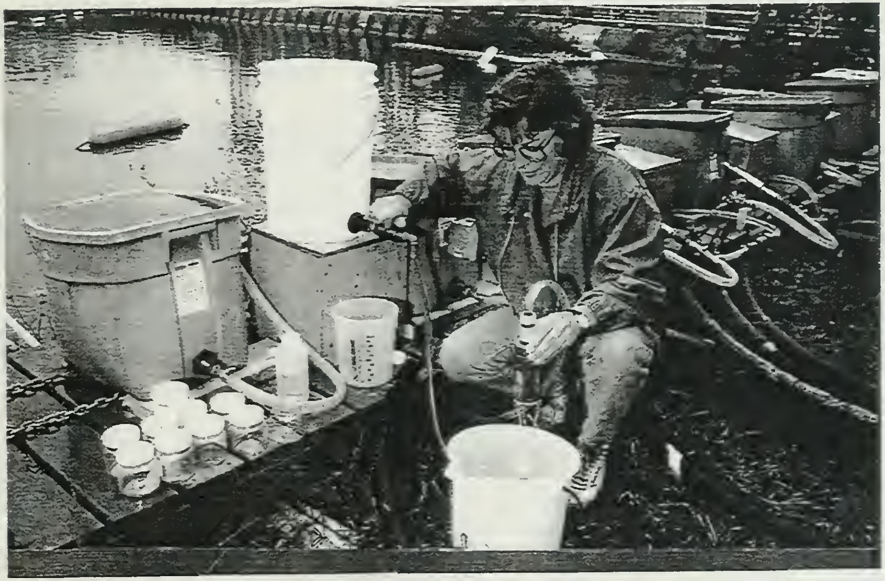


FIGURE 4. Technician taking sample for density analysis

Products were rated on the basis of ease of maintenance, ability to removing incoming veligers and juveniles from the water stream and prevention of settlement in the intake pipe and settling chamber.

3.1) Product Testing Results

3.1.1) Alex Milne - Zebra Guard Sand Cottage Filter (Product A)

Product Installation and Maintenance (Figure 5a, b)

This product was extremely difficult to install and maintain. For the most part this was due to its excessive weight (approx. 250 pounds) when filled with the filter media as supplied by the manufacturer. Even when diver assisted, great difficulty was experienced transporting the unit to the intake location and positioning the unit properly. This product cannot and should not be installed from a small boat. If installation is attempted in this manner, capsizing of the boat and serious injury could result. Professional installation is recommended. The manufacturer supplies recommend installation procedures.

The manufacturer suggests filter backflushing every 50,000 gallons which in the case of our installation, would mean once every 10-12 days. We found this frequency to be inadequate and the procedure had to be undertaken more frequently (approximately twice weekly), particularly toward the end of the project. There also appears to be insufficient diffusion of the backflushed water across the filter to adequately "re-fluff" the filter media. Only a small area in the corner of the filter immediately surrounding the backflush port was being effectively backflushed.

On eleven occasions during the study the pump for this system lost prime and failed to pump water due to clogging. On these occasions the unit had to be backflushed for thirty minutes or more before the pump could be re-started.

It should be noted that turbidity in this vicinity was relatively high (9 NTU or higher on occasion) which may be more than is experienced in many SVWU systems.

Other problems encountered during installation included difficulty keeping the copper screen covering the top of the filter box in place and poor seals around the intake line entering the filter box.

As part of the filter package a Zebra Guard wax was supplied for application to the outside surfaces of the filter box and associated piping to inhibit mussel growth and facilitate easy removal of adult mussels.

Product Performance

The Alex Milne Zebra Cottage filter was effective at removing incoming veligers from the water stream (Figure 14). Mean veliger densities passing through the filter in water samples over the study period were $703.1/m^3$ compared to a mean density passing through the adjacent control system of $11,083/m^3$.

The day to day % removal varied significantly over the study, probably due to veliger age and therefore size variability between days. Unfortunately, analysis did not include age distribution.

Microscopic analysis of the inside surfaces of the four preserved sections of intake pipe did not reveal any mussel colonization (Figure 15). The PVC substrate plates from the holding tank were also found to be free from mussel growth (Figure 16), however, three juvenile mussels were found in samples taken from the inside walls of the holding tank (Figure 17). These mussels measured 1 - 2 mm in size and resulted in a colonization density of $.002/cm^2$. Visual inspection of the remaining sections of intake pipe did not reveal any mussel colonization.

The Zebra Guard wax did not inhibit mussel growth (which was extensive) on outside surfaces. Mussels were equally easy to remove from all surfaces on all systems and so no significant advantage was observed as a result of wax application.

3.1.2) Alex Milne - Zebra Cartridge Filter (Product B)

Product Installation and Maintenance (Figure 6a, b)

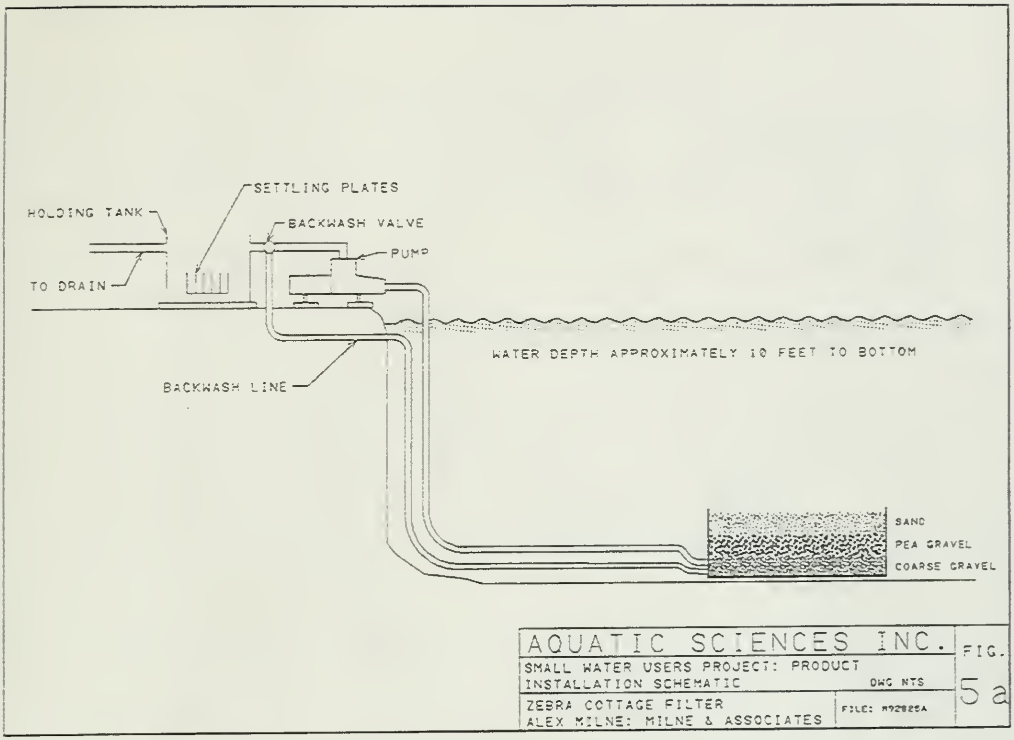
This product was also relatively difficult to install when compared to the other filters in this study due to its weight, awkward shape and relative fragility. It was awkward to position properly and installation would require two strong individuals. Two of the cartridges broke off and had to be replaced during installation.

A new unit was supplied by the manufacturer after he was informed of the problems. This unit was installed on October 1, 1992, however this did not allow proper testing prior to trial completion.

Despite the difficulties with installation, the unit required very little maintenance during the testing period and did not clog. It is possible that this was due in part to an improper seal which may have been created between the cartridges and the filter housing during installation.

Product Performance

When evaluating the ability of this product to eliminate downstream mussel infiltration and settlement, it must be kept in mind that some damage was done to the product during installation and while repairs seemed to be adequate the results remain in question.



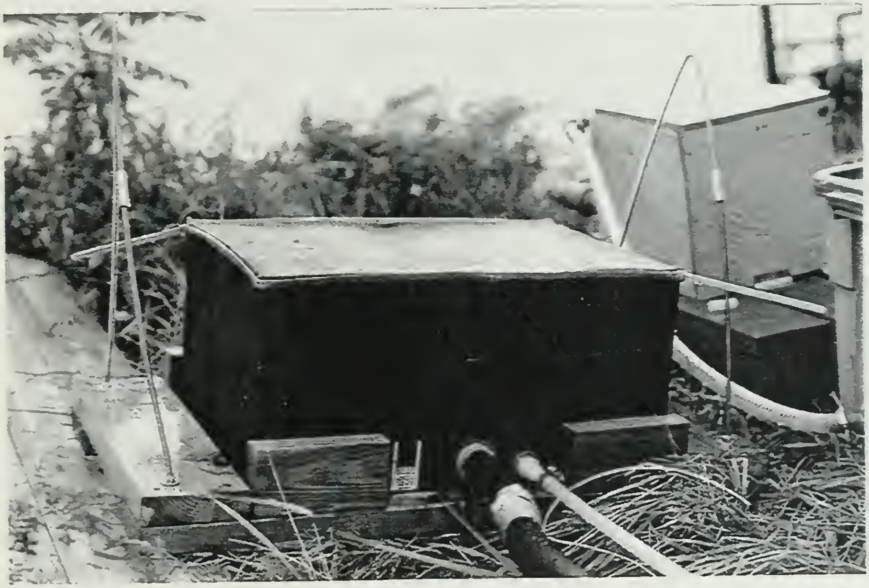
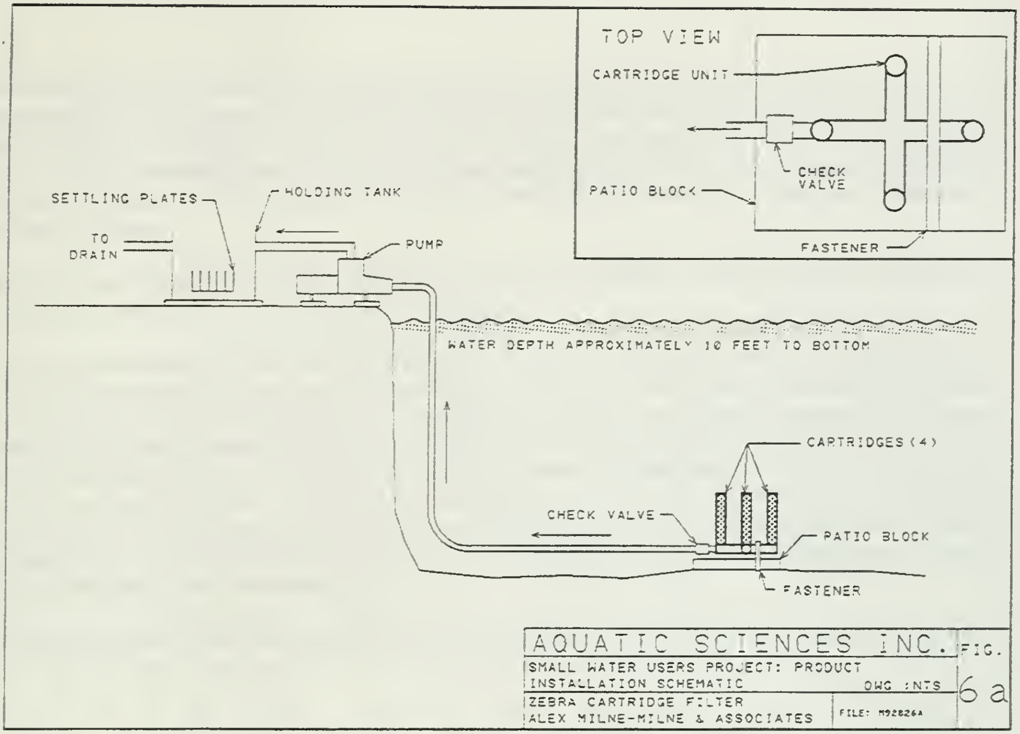


FIGURE 5b. Alex Milne Zebra Cottage Filter



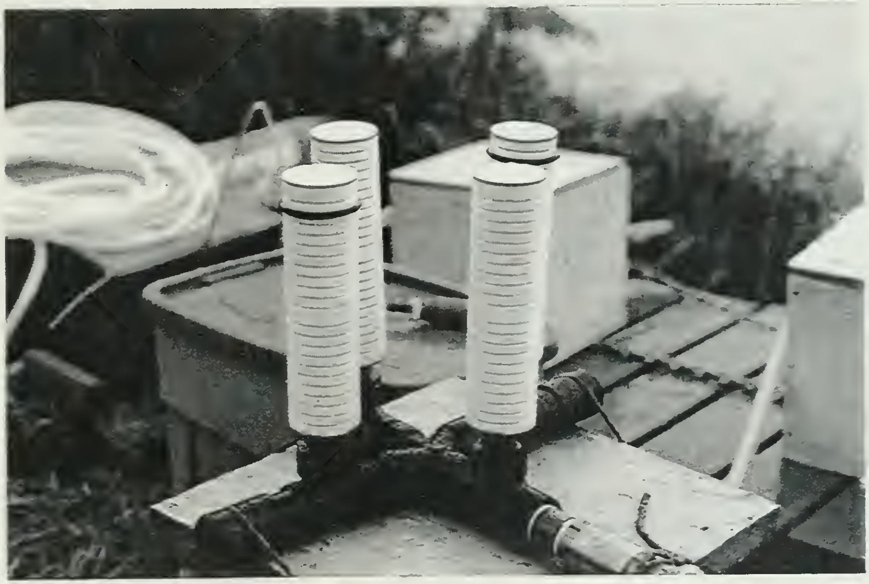


FIGURE 6b. Alex Milne Zebra Cottage Filter

Mean veliger densities passing through this system were approximately 30% to 50% less than those entering the control systems. The mean veliger density entering this system over the study period was 3, 239/m^3 as compared to the control systems which saw mean densities of 11,083/m^3 and 10,799.2/m^3 respectively over the period of the study (Figure 14). This number included a substantial number of settling stage veligers which entered the system and subsequently colonized the inside surfaces.

Again % removal varied day to day which may have been a function of veliger size on a given day. Veliger size distribution was not done in this study.

Juvenile size mussels (1-2 mm) were found on all three of the surfaces that were examined. In the case of the intake pipe, three juvenile mussels were found on the four sample sections. The total area sampled was approximately 200 cm^2, therefore the settled mussel density was calculated to be 0.004 mussels/cm^2 (Figure 15). Analysis of the PVC settling plates inside the holding tank at the end of the study period also revealed mussel colonization. A total area of 234 cm^2 was sampled from three substrate plates. Four mussels were found over the three plates resulting in a density of .0056 mussels/cm^2 (Figure 16). Holding tank side scrapings revealed even more mussel growth (Figure 17). A total of 107 juvenile size mussels were found in the sample. The calculated density for the tank sides was 0.058 mussels/cm^2.

Visual inspection of the unscraped portions of intake pipe revealed sporadic mussel growth over most of the length of the pipe.

3.1.3) D.R. Lowther Consulting - Cartridge Filter (Product D)

Product Installation and Maintenance (Figure 7a, b)

This filter product was easily attached to the end of the pipe and very easily installed. A footvalve was not needed but a check valve had to be installed immediately downstream of the filter to keep the line primed when the pump was not operating. The installation could be accomplished by one person.

The inner filter cartridge began to clog relatively quickly, (approximately 2 weeks) resulting in reduced flow through the holding tank. On two occasions (August 30, September 22) the cartridge clogged to the point where there was zero flow, eventually overheating and shutting down the pump. When this happened the line had to be pulled up and the cartridge replaced with a new one supplied by the manufacturer.

Product Performance

This product effectively removed veligers from the incoming water. The filter was successful at removing approximately 94% of the veligers from the ambient water relative to the two control systems (Figure 14). Mean veliger densities sampled passing through this system were 661.3/m^3.

Percent removal varied day to day, likely relating to veliger size. No mussels were found on the inside surfaces of the intake pipe sections. A total of three mussels were found on the settling plates and 41 mussels on the holding tank walls at the end of the evaluation. Densities were $0.043/cm^2$ and $0.02/cm^2$ respectively (Figure 16, 17).

Visual inspection of the intake pipe did not indicate any mussel colonization.

3.1.4) MYCO Industries (Aim Trading Co.) - Cartridge Filter (Product E)

Production Installation and Maintenance (Figure 8a, b).

This product was easily installed at the end of the intake pipe. A cottage owner could easily install it with little effort. A foot valve can be threaded directly onto the intake port on the filter housing which would make it easily removable for cleaning.

Similar problems with maintenance were experienced with this product as with the Lowther filter product. The cartridge clogged rapidly (within two weeks), resulting in reduced flow (Table 3). On two occasions (August 30 and September 23) the cartridge had to be replaced due to complete filter clogging.

Product Performance

Of the products tested in this study, this filter was the most effective in terms of veliger removal from the water column as is indicated in Figure 14. The mean density of veligers passing through this system was calculated to be $101.1/m^3$ in comparison with the nearest control which was $11,083/m^3$. Veliger size distribution was not carried out however, it is speculated that those veligers that passed through the filter were younger and smaller mussels.

The analysis of the intake pipe sections revealed only 1 juvenile mussel which translated into a density of $0.0014/cm^2$. Three plates were scraped from the holding tank and the subsequent analysis also revealed only 1 mussel. This also resulted in a calculated density of $0.0014/cm^2$. No mussels were found on the holding tank walls or on the remaining sections of intake pipe which were visually inspected.

3.1.5) ISP (Canada) Inc. - Surface Cartridge Filter (Product F)

Product Installation and Maintenance (see Figure 9a, b)

Although the design of this product, as it was tested, necessitated that it be surface mounted between the pump discharge and the holding tank it could easily be adapted by the manufacturer to be installed at the end of the pipe, with modifications to allow installation on the suction side of the pump. This product can easily be installed by one person.

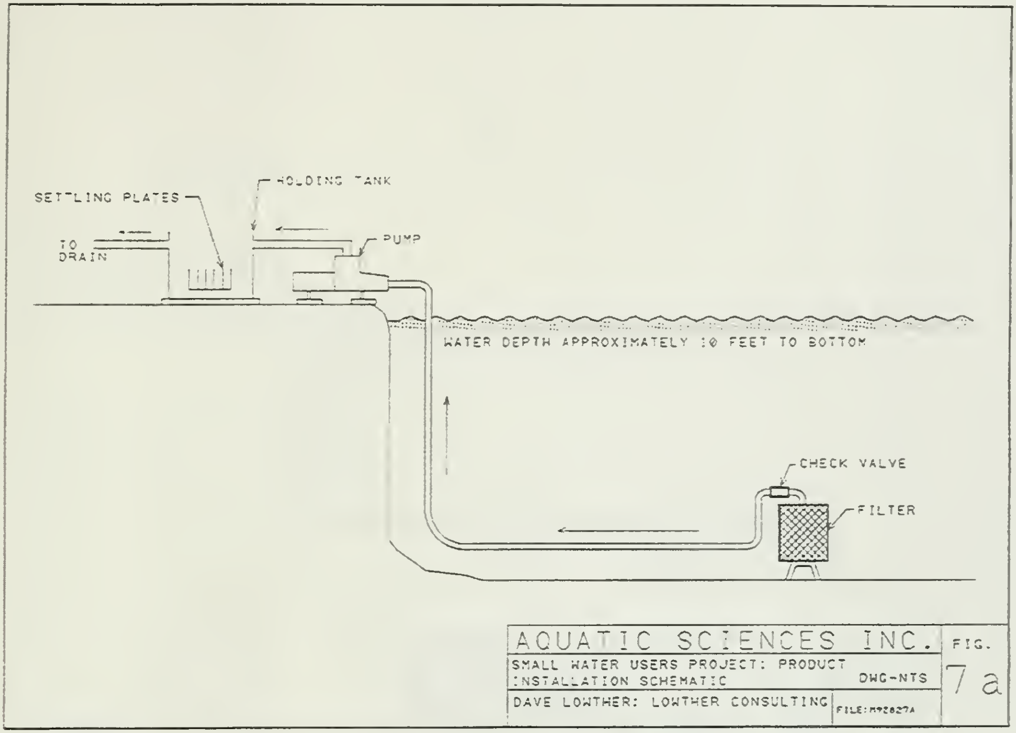

SETTLING PLATES
HOLDING TANK
TO DRAIN
PUMP
WATER DEPTH APPROXIMATELY 10 FEET TO BOTTOM
CHECK VALVE
FILTER
AQUATIC SCIENCES INC.
SMALL WATER USERS PROJECT: PRODUCT INSTALLATION SCHEMATIC
DWG-NTS
DAVE LOWTHER: LOWTHER CONSULTING
FILE:M92827A

FIG. 7a

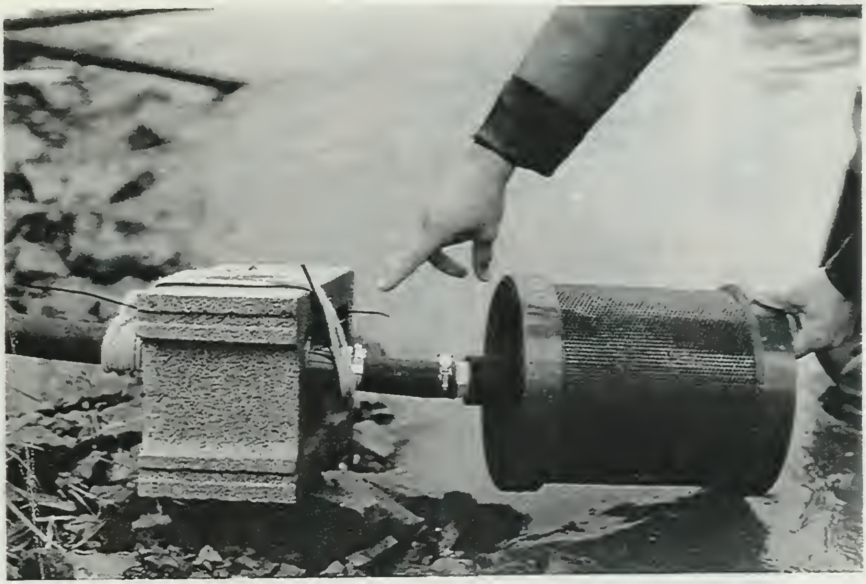
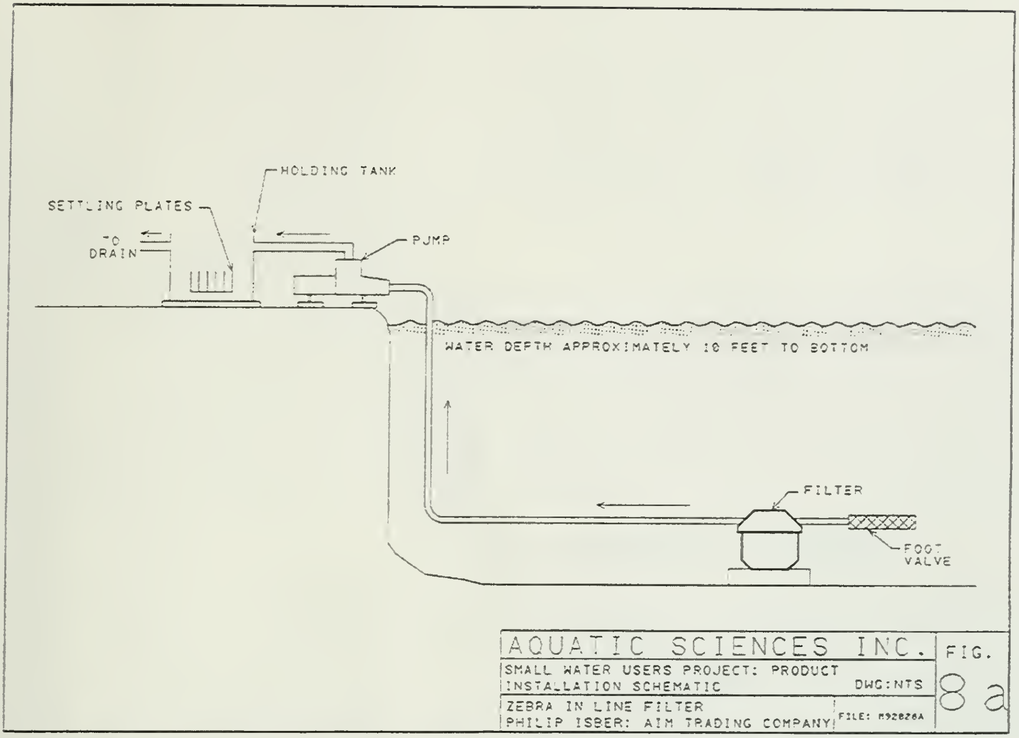


FIGURE 7b. Lowther Consulting Cartridge Filter


HOLDING TANK
SETTLING PLATES
TO DRAIN
PUMP
WATER DEPTH APPROXIMATELY 10 FEET TO BOTTOM
FILTER
FOOT VALVE
AQUATIC SCIENCES INC.
SMALL WATER USERS PROJECT: PRODUCT INSTALLATION SCHEMATIC
DWG:NTS
ZEBRA IN LINE FILTER
PHILIP ISBER: AIM TRADING COMPANY
FILE: M92826A
FIG. 8a

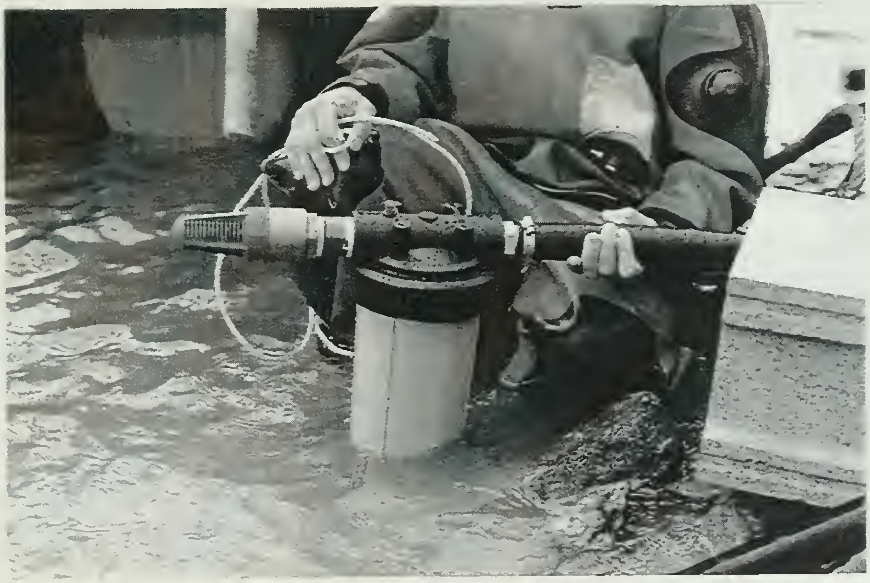
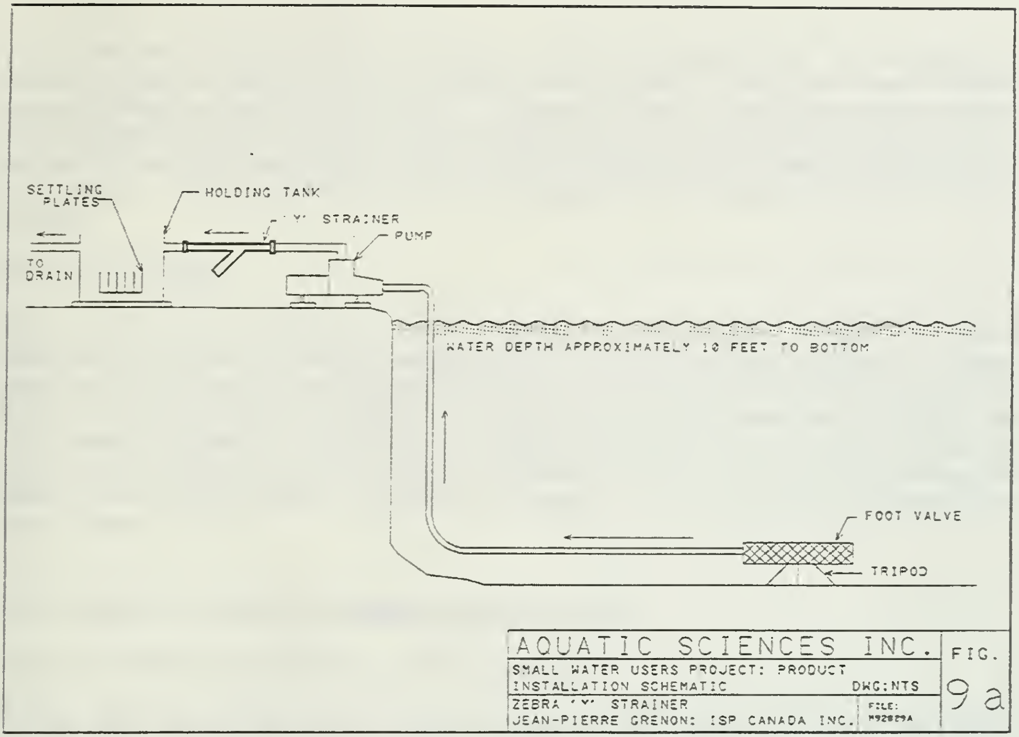


FIGURE 8b. MYCO Industries (Aim Trading Co.) Cartridge Filter


SETTLING PLATES
HOLDING TANK
'Y' STRAINER
PUMP
TO DRAIN
WATER DEPTH APPROXIMATELY 10 FEET TO BOTTOM
FOOT VALVE
TRIPOD
AQUATIC SCIENCES INC.
SMALL WATER USERS PROJECT: PRODUCT INSTALLATION SCHEMATIC
DWG:NTS
ZEBRA 'Y' STRAINER
JEAN-PIERRE GRENON: ISP CANADA INC.
FILE: M92829A
FIG. 9 a

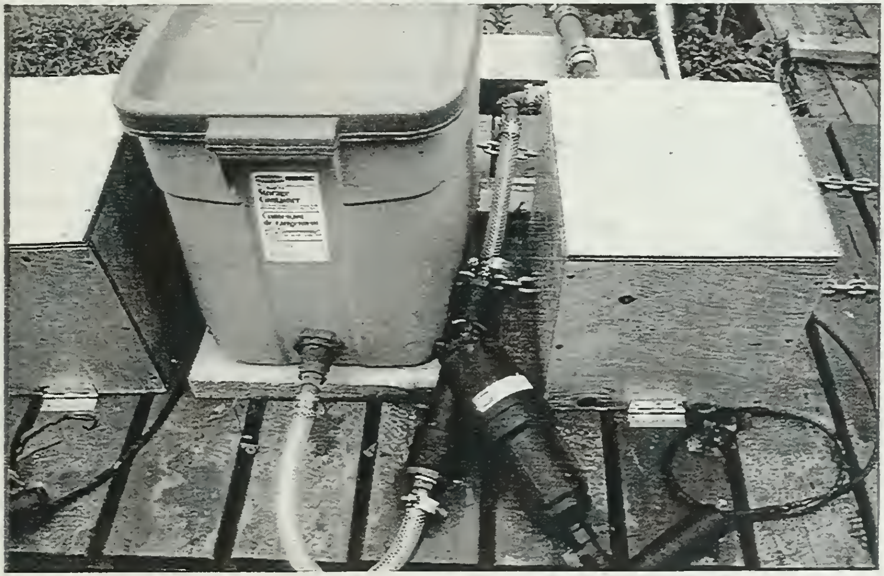


FIGURE 9b. ISP Canada "Y' Filter

The product was extremely easy to maintain due to it's filter cartridge design. The cartridge is reusable and took less than five minutes to remove, rinse and clean. This process would obviously be complicated by an end of pipe installation. The cartridge needed cleaning approximately every 10 days however this did not present a major problem since it was so easily cleaned and put back on line. The cartridge was removed from the filter housing and flushed under running water for 2 - 3 minutes. In the occasional case of severe clogging, a coarse brush was used to clean the cartridge.

Product Performance

This product performed relatively well when compared to the other filter products. It removed approximately 95% of the incoming veligers relative to the control systems (Figure 14). Mean veliger densities sampled in this system over the period of this trial were $547/m^3$ as compared with the nearest control which was $11,083/m^3$. Percent removal varied between days, most likely due to variation in veliger sizes. Many juvenile mussels were found on the sections of intake pipe however this was to be expected since it was unprotected. The settling plates in the holding tank, which received filtered water, were found to be mussel free. This was also the case for the tank walls (Figure 15 - 17).

3.1.6) Harcourt Technologies - Magnetic Units (Product G)

Product Installation and Maintenance (Figure 10a, b)

This product consisted of a series of magnets which clamp on to the outside of the intake pipe at the extreme end of the pipe (Figure 10a). The product is easily installed by one person and requires no maintenance. Two sets of magnets were tested during the field trials.

Product Performance

The exact mechanism by which this product is supposed to inhibit mussel growth is not well understood. The manufacturer suggested that all incoming veligers which passed through the magnetic fields would be killed by damage to cell structure. Unlike filter products, veligers were not prevented from entering this system.

Veliger mortalities were often slightly higher in this system than the controls, (2 - 20% increases) but a substantial number of viable veligers were still entering the system. The mean density of veligers entering this system over the study period was calculated to be $12,983/m^3$ which was actually marginally higher than controls.

On August 31, the original magnets were replaced by a stronger set. Results did not improve significantly.

Twenty six juvenile mussels were found on the intake pipe surfaces resulting in a calculated density of $0.036/cm^2$ (Figure 14). Mussel counts on the settling plates and on the holding tank walls were 33 and 314 resulting in densities of $0.047/cm^2$ and $0.170/cm^2$ respectively.

3.1.7) York Energy - Ion Stick (Product H)

Product Installation and Maintenance (Figure 11)

This product is an electrostatic device more commonly applied to reduce or remove scale and calcium build up in closed loop water systems. As per manufacturer's instructions this product was to be installed either on the pump discharge between the pump and the holding tank or in the holding tank itself. The holding tank installation was chosen for its ease of installation. The product was mounted through the side walls of the holding tank and positioned just above the settling plate rack (Figure 11).

The installation was physically difficult and professional installation is recommended to ensure safe operation.

Product Performance

This product did not seem to inhibit or inactivate the incoming zebra mussel veligers either through increased mortalities or reduction of settlement in intake pipe or holding tank. The mean density of veligers entering this system was $14,471/m^3$ which was somewhat higher than the mean number entering the adjacent control system (Figure 14).

A total of 41 mussels were recovered from pipe sections, 12 mussels from settling plates and 294 from tank walls, which resulted in calculated settling densities of $0.057/cm^2$, $0.017/cm^2$ and $0.159/cm^2$ respectively.

3.1.8) Modern Concepts/WHW Resource Management Ltd. - Hydrodynamics Units [6JR(I)6JR-Z(J)]

Production Installation and Maintenance (Figure 12a, b)

These products were originally designed to prevent or remove scale build up essentially by changing the water characteristics to make calcium unavailable. This would in turn make shell build up difficult for growing mussels thus preventing serious infestation. The two products apparently differed based on relative strength. The 6JR-Z was a more powerful unit than the 6JR and therefore better results were expected.

Product installation was somewhat complicated, relative to the other products tested. This was mainly due to the fact that the units required continuous flow in order to be effective. To

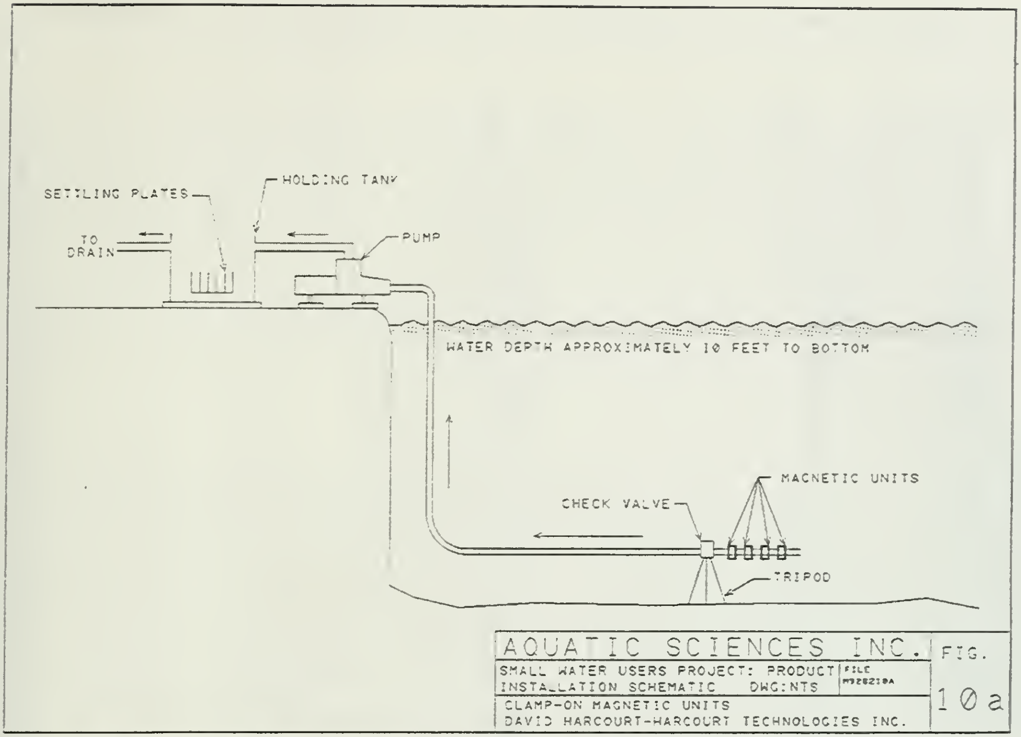

SETTLING PLATES
HOLDING TANK
TO DRAIN
PUMP
WATER DEPTH APPROXIMATELY 10 FEET TO BOTTOM
MAGNETIC UNITS
CHECK VALVE
TRIPOD
AQUATIC SCIENCES INC.
SMALL WATER USERS PROJECT: PRODUCT INSTALLATION SCHEMATIC
DWG:NTS
FILE
CLAMP-ON MAGNETIC UNITS
DAVID HARCOURT-HARCOURT TECHNOLOGIES INC.

FIG. 10a

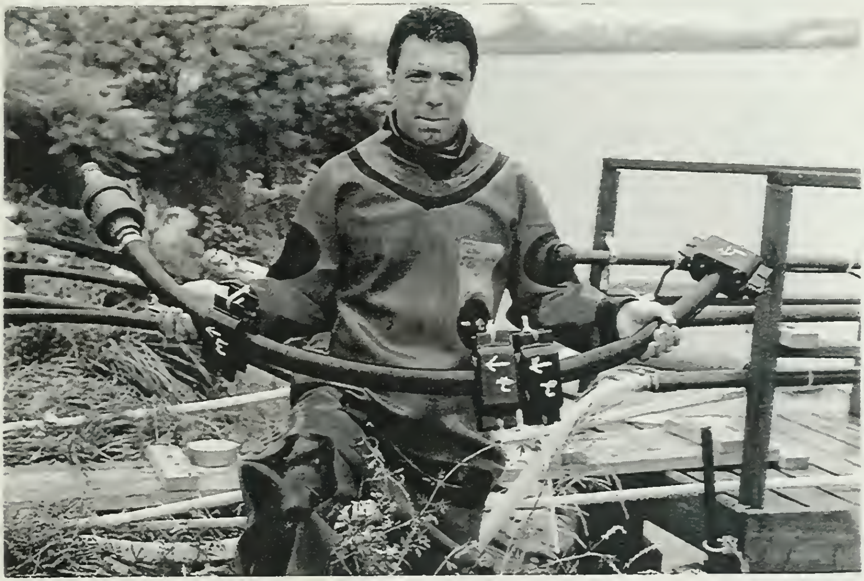
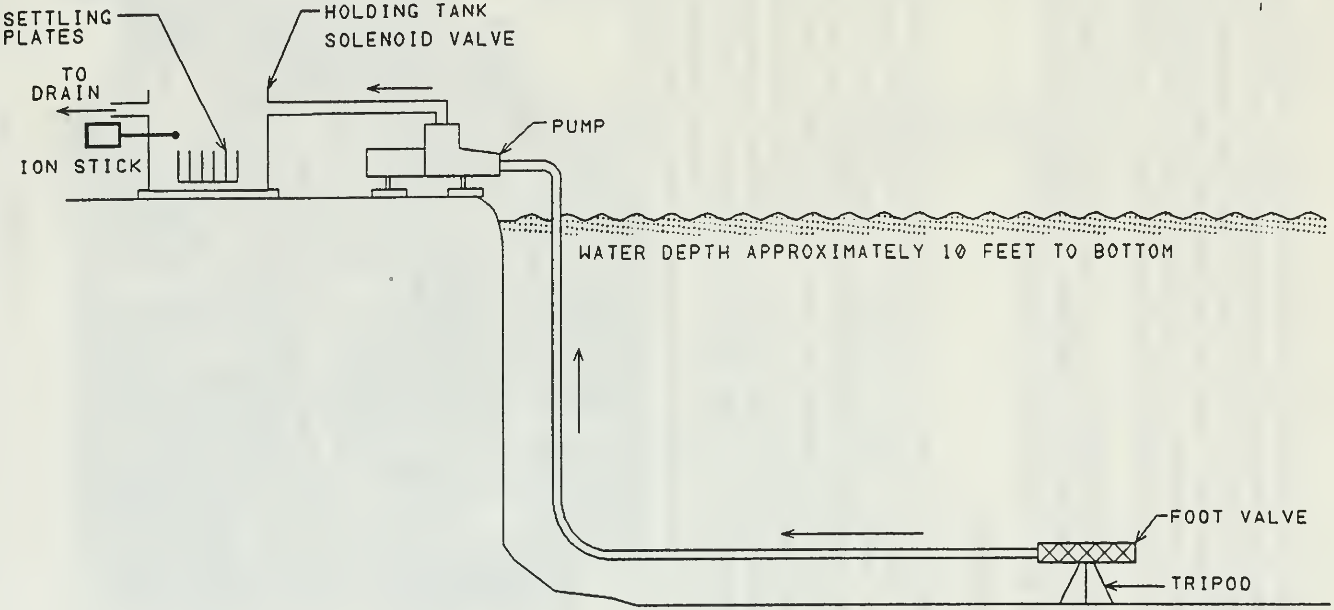


FIGURE 10b. Harcourt Technologies - Magnetic Units



AQUATIC SCIENCES INC.

SMALL WATER USERS PROJECT: PRODUCT
INSTALLATION SCHEMATIC
DWG:NTS

ART SIMPSON: YORK ENERGY
ION STICK

FILE: M928211A

FIG.
11

accommodate this requirement, while still mimicking a demand only system, a timer operated solenoid valve (normally closed) was installed downstream of the units between the pump and the holding tank. The water pump remained on during the entire test period and recirculated water back to a diffuser which "bathed" the foot valve with treated water. The intake would then draw in a portion of treated water with untreated water which would circulate within the semi-closed loop until the Solenoid valve opened, allowing water into the holding tank (Figure 12a).

This product would probably have to be installed by an experienced plumber and/or electrician because of it's continuous flow requirements. It would also significantly shorten the lifespan of the water pump due to its continuous operation requirement.

Product Performance

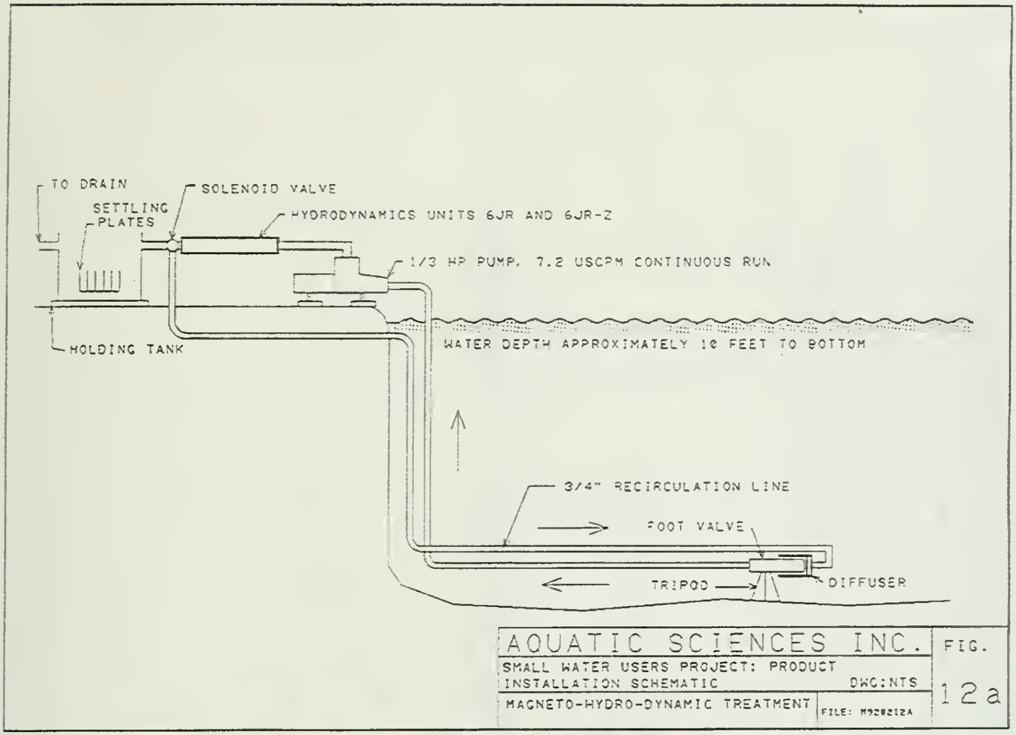
The two units tested seemed to show promise inhibiting growth in the intake line as illustrated in Figure 15. There were no mussels found in the intake line for unit (I) and only 3 mussels were found in the unit (J) system, resulting in a colonization density of 0.004/cm^2. This lack of settlement becomes more significant when we take into account the greatly enhanced opportunity for settlement due to continuous flow mode. Veliger densities entering both systems were higher than the control systems as unit (I) received two times the control at 22,665/m^3 and unit J received 11,022/m^3 or similar to controls (Figure 14). This trend was also observed when analysis of the PVC settling plates and tank side scrapings was completed. Analysis of PVC plates and tank sides from unit I resulted in discovery of 76 and 1,031 mussels respectively which yielded calculated densities of 0.11 and 0.56/cm^2. Unit J showed settlement of 29 mussels on plates and 538 mussels on tank walls which resulted in calculated densities of 0.04 and 0.29/cm^2 respectively.

3.1.9) Ron Whitcombe - Surface Sand Filter (Product K)

Product Installation (Figure 13)

This product is similar in design to the Milne sand filter, however this product is designed for surface installation. The product that was supplied by the manufacturer was installed as per instruction but was never "on line" for several reasons.

There was a poor seal around the lid of the unit which allowed air to be drawn in, eventually causing the pump to lose it's prime. This problem was corrected by ASI technicians but more air leaks were found around the handles of the box and the sides of the box began to collapse when filled with water. The sides were supported using pieces of 2 x 6 lumber and steel strapping and the detectable air leaks were sealed however the unit could not be made air tight which caused frequent pump failure. After two weeks of unsuccessfully working with this unit to get it on line, it was abandoned and the system left off. The manufacturer was informed of the units status and indicated that another would be supplied. A replacement was never delivered.


TO DRAIN
SOLENOID VALVE
SETTLING PLATES
HYDRODYNAMICS UNITS 6JR AND 6JR-Z
1/3 HP PUMP, 7.2 USGPM CONTINUOUS RUN
HOLDING TANK
WATER DEPTH APPROXIMATELY 10 FEET TO BOTTOM
3/4" RECIRCULATION LINE
FOOT VALVE
TRIPOD
DIFFUSER
AQUATIC SCIENCES INC.
SMALL WATER USERS PROJECT: PRODUCT INSTALLATION SCHEMATIC
DWG:NTS
MAGNETO-HYDRO-DYNAMIC TREATMENT
FILE: M920212A
FIG. 12a

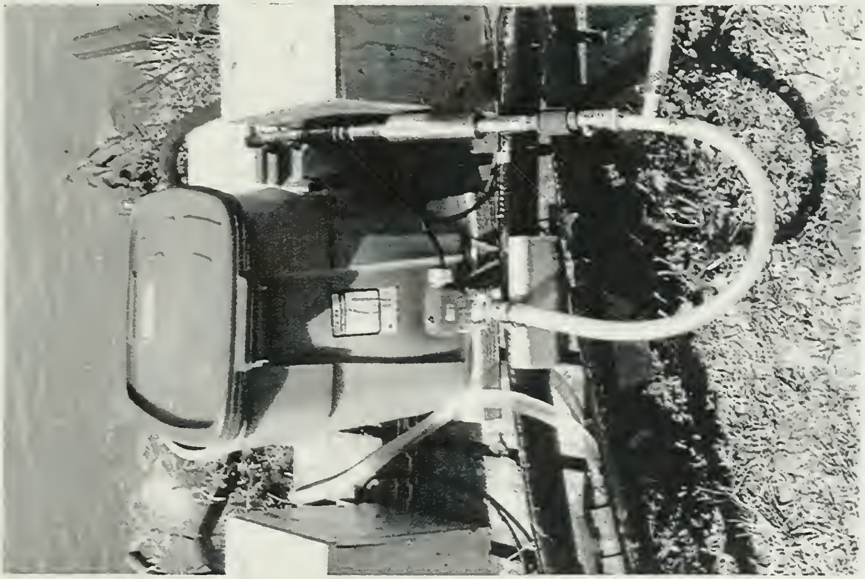
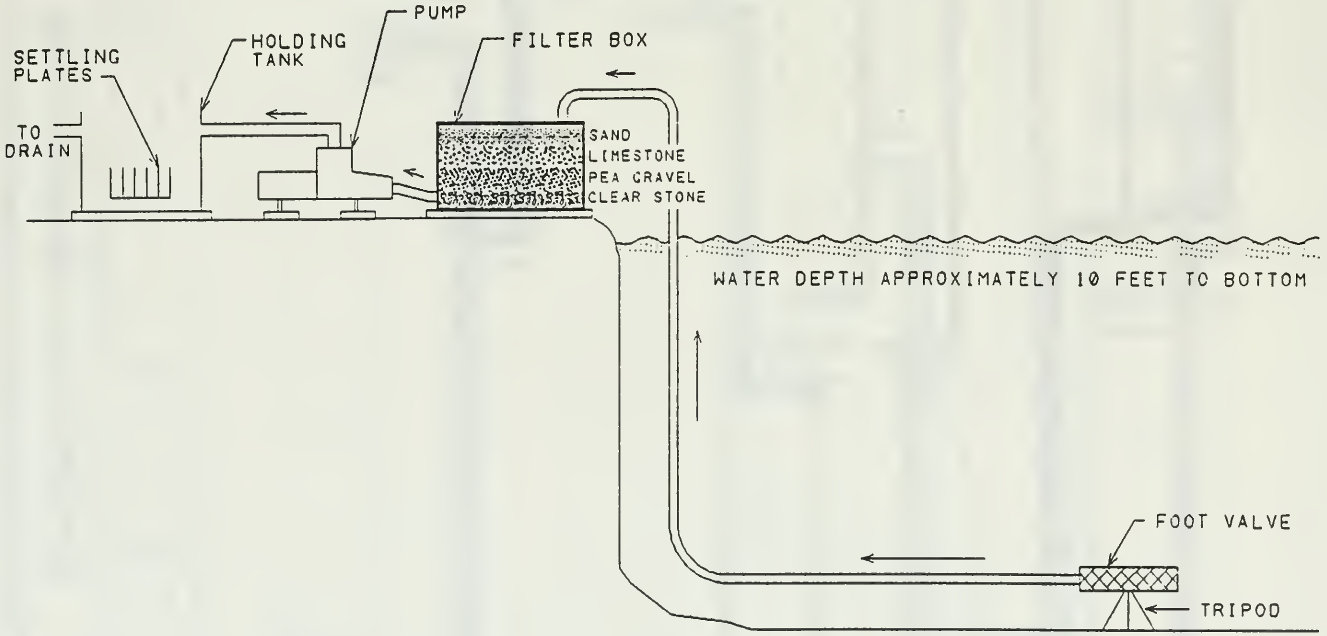


FIGURE 12b. Modern Concepts/WHW - Hydrodynamic Units



AQUATIC SCIENCES INC.

SMALL WATER USERS PROJECT: PRODUCT INSTALLATION SCHEMATIC

ZEBRA MUSSEL FILTER
RON WHITCOMBE - ZEBRA CONTROL DWG-NTS

FIG 13

FIG. 14 MEAN VELIGER DENSITIES SAMPLED IN EACH PRODUCT SYSTEM AND CONTROL SYSTEM

(means of daily samples over the entire study period)

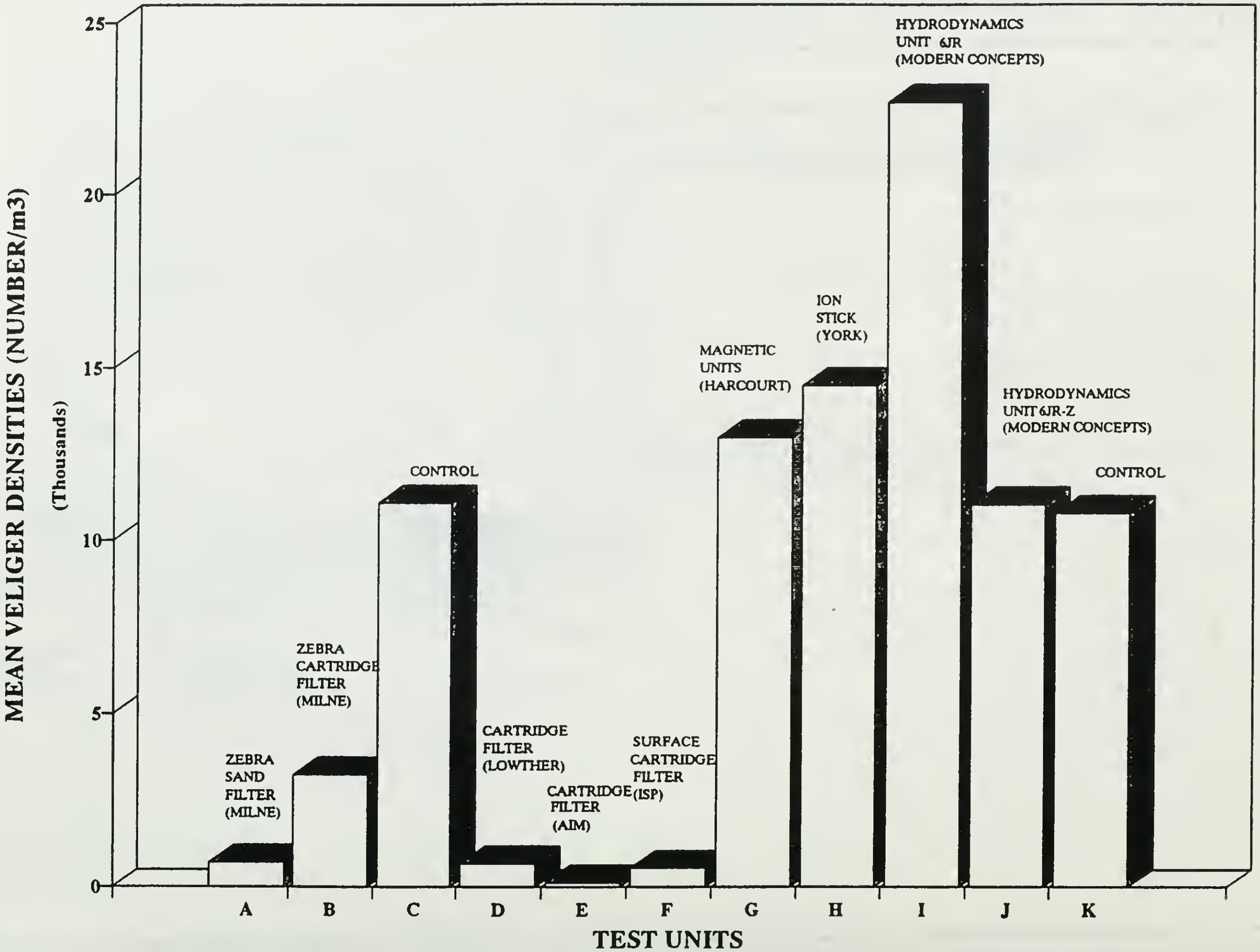


FIG. 15 JUVENILE MUSSEL DENSITIES SAMPLED IN EACH PRODUCT SYSTEM AND CONTROL SYSTEM (INTAKE PIPES)

* intake pipes not protected

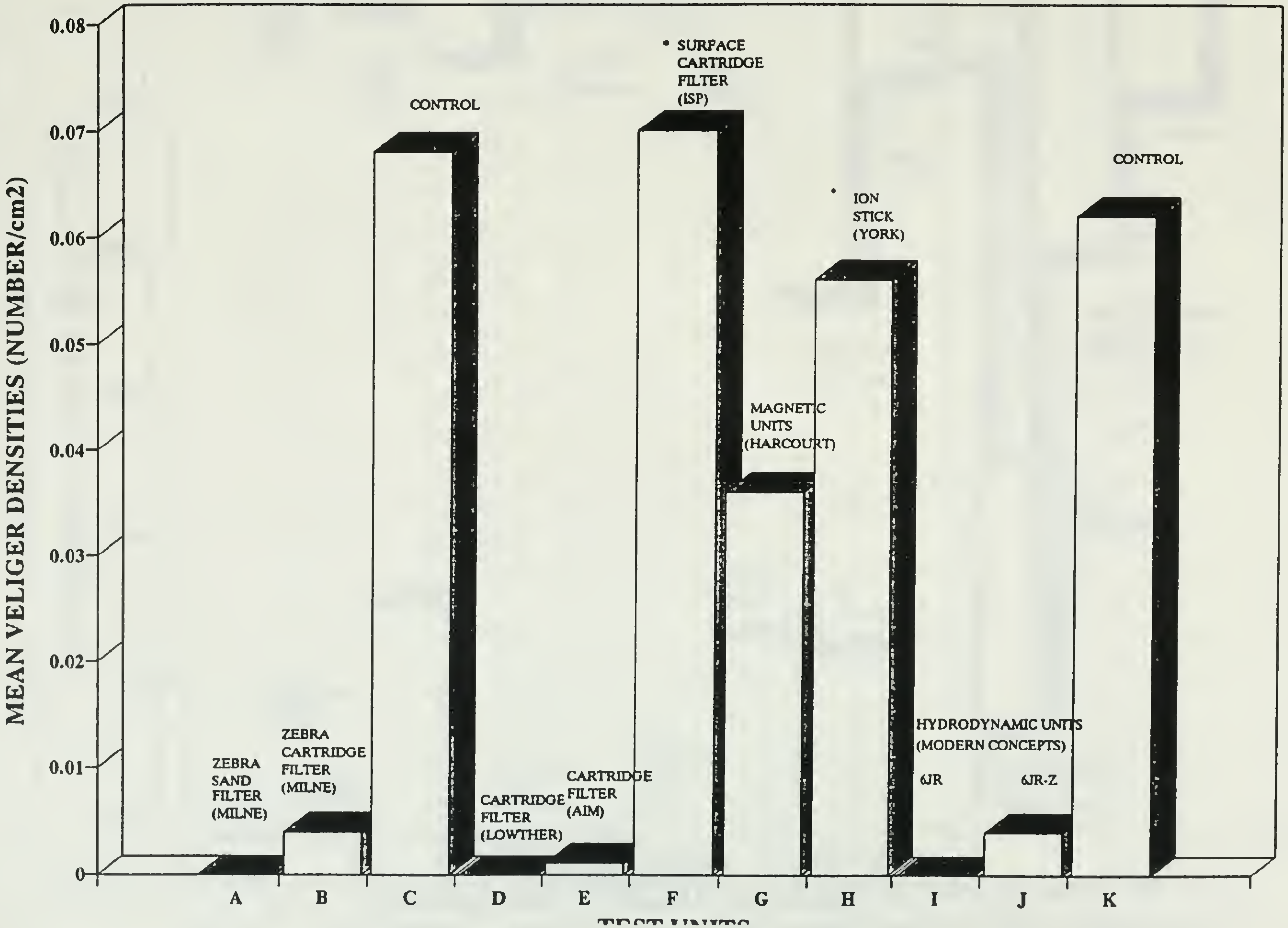


FIG. 16 JUVENILE MUSSEL DENSITIES SAMPLED IN EACH PRODUCT SYSTEM AND CONTROL SYSTEM (SETTLING PLATES)
(sampled at end of study period)

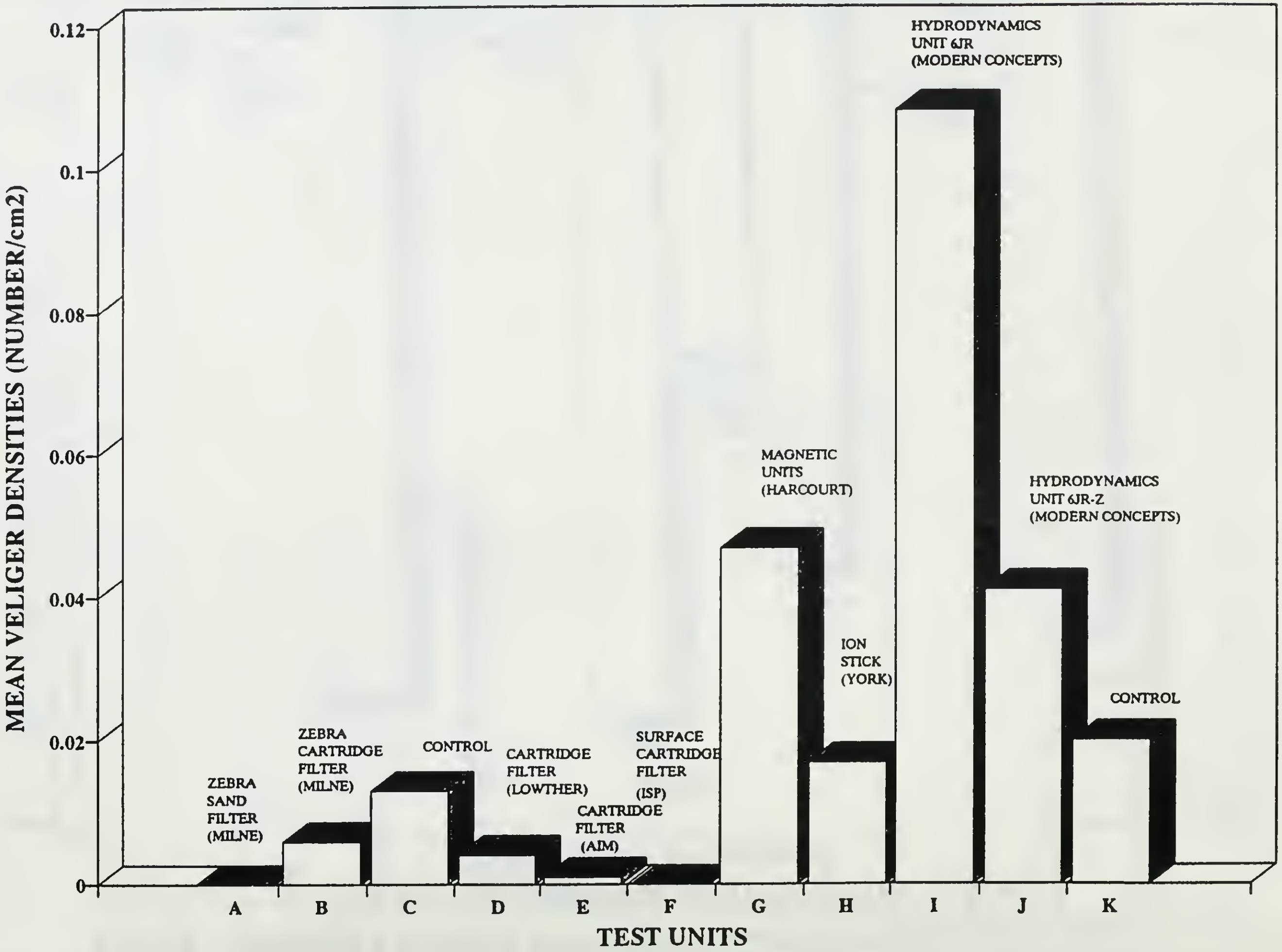
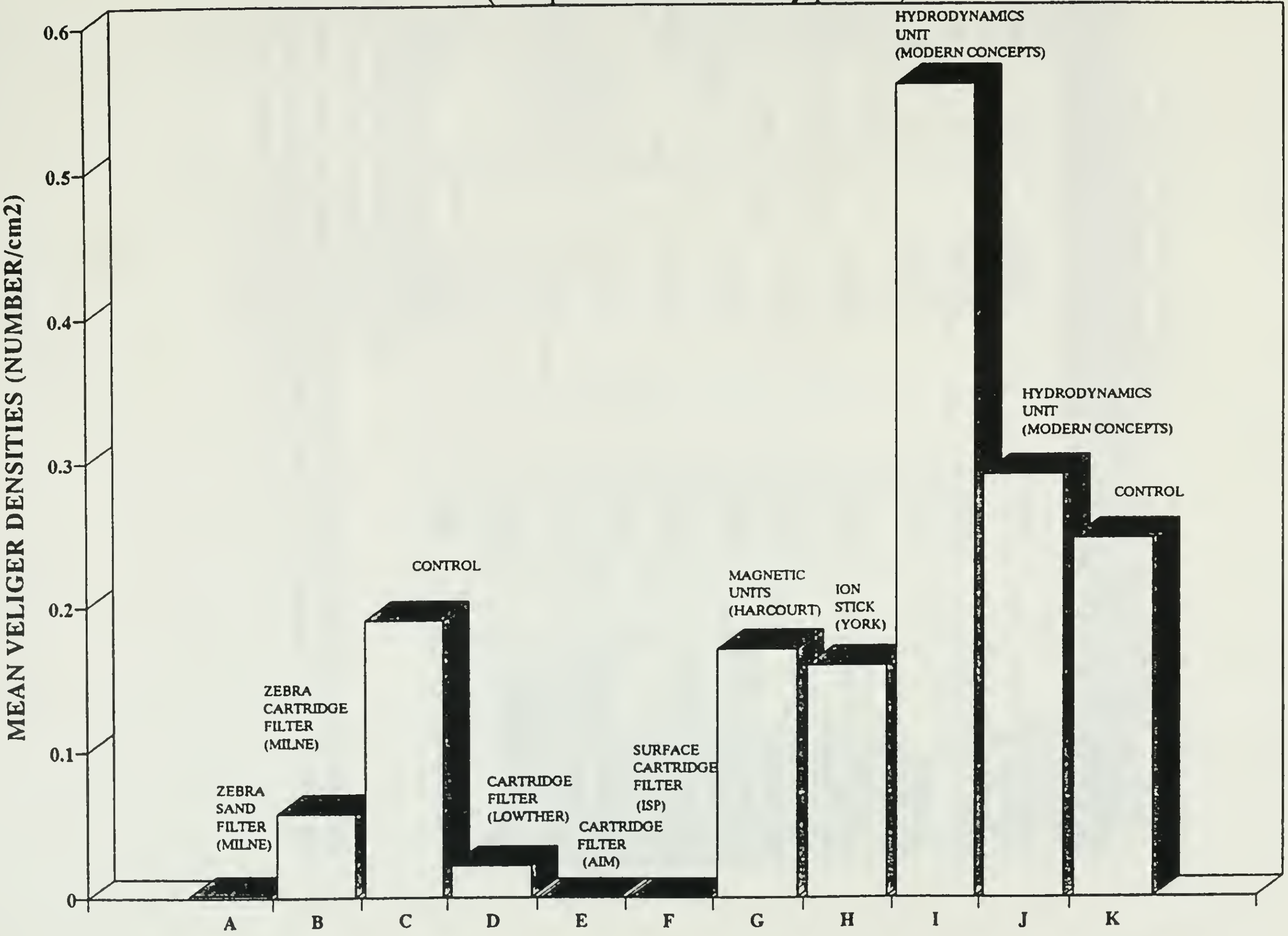


FIG. 17 JUVENILE MUSSEL DENSITIES SAMPLED IN EACH PRODUCT SYSTEM AND CONTROL SYSTEM (TANK WALLS)

(sampled at end of study period)



Product Performance

No sampling was done on this system due to problems previously described with this product.

4.0) DISCUSSION

In order to provide a yardstick of performance for each of the products tested, a point scoring system was devised which took into account the products performance in terms of inhibition of mussel growth, ease of installation and amount of maintenance required to keep the product operating. Product design was also taken into consideration. Points were given on a scale of 0 to 10, 10 being the highest. Each of the product performances will be discussed individually and the scoring results will be summarized at the end of the discussion section (Table 2).

4.1) Alex Milne - Zebra Sand Filter

It is apparent from analysis of results that this product is quite efficient at removing veligers from the incoming water. The problems with it lie in the difficulties encountered during installation and the frequent maintenance it required during the latter part of the study period.

It would not be wise or even feasible to attempt installation of this product without commercial grade equipment.

The fact that the filter was becoming "loaded" with sediment which resulted in clogging was probably due to inadequate diffusion of backwash water to reflush the filter media. It may also have been due to filter media lodged in the check valve which prevented it from closing. Apparently the manufacturer has since improved this feature to enhance the backflush capability.

If this product were to be installed in a heavily infested lake a clean source of water for backflushing would have to be established. If source water were used for this purpose the filter and associated downstream plumbing could become contaminated with mussel veligers.

This product scored well in prevention of downstream mussel settlement however installation and maintenance was considered a major drawback for the average SVWU, (Table 2).

4.2) Alex Milne - Zebra Cartridge Filter

Results of tests performed on this product are considered suspect due to the potential for damage incurred during installation. Difficulties with installation were considered a major drawback for average SVWU, (Table 2).

The manufacturers improved version appeared to be more stable which would make damage during installation less likely. Unfortunately this product could not be properly tested as mussel reproduction was close to being finished.

4.3) D.R. Lowther Consulting - Cartridge Filter

Although the design of this filter allowed for easy installation it was subject to frequent clogging resulting in reduced flow. The problem of filter clogging could be alleviated by installing a larger size (50 - 75) micron cartridge or prefilter and/or some sort of back flushing system. A filter retrieval system which would allow the SVWU to change cartridges without removing intake pipe or diving on the intake, would also make this system easier to maintain.

In general this product performed well and did not allow any zebra mussel colonization of the intake line. Because of this product's simple design and ease of installation and maintenance it scored reasonably high on most categories, (Table 2). With a few modifications it could be useful for a small cottage water intake system.

4.4) MYCO Industries (AIM Trading Co.) - Cartridge Filter

Many of the problems experienced with this product were similar to the problems encountered with the product from Lowther Consulting. The product proved to be efficient at screening out incoming veligers but tended to clog quite easily. A filter retrieval system to allow cartridge replacement without removing the intake pipe or diving on the intake would make maintenance much easier.

Again, prefiltering, larger diameter cartridges or back flushing ability may improve overall performance. This product also scored relatively high in all point categories because of its simple design, performance, and ease of installation, (Table 2).

4.5) ISP Canada Inc. - Surface Cartridge Filter

This filter product required surface installation on the discharge side of the pump, between the pump and holding tank.

This product was very efficient at removing incoming veligers and allowed no zebra mussel colonization downstream of its deployment point. The re-usable cartridge allowed for easy removal and cleaning. The reusable aspect of this filter also improves it's economy and attractiveness from an environmental point of view.

If this filter product could be adapted by the manufacturer to a suction side installation (at the foot valve) and an easy retrieval system incorporated in the manufacturers package it would definitely be recommended to protect SVWU systems.

The product scored well in all categories with the stipulation that it could be moved to protect the intake pipe, (Table 2).

4.6) Harcourt Technologies - Magnetic Units

Although veliger mortalities were found to be slightly higher in this system, as compared to the control systems, it is obvious from the data that many viable veligers were still entering the system and subsequently colonizing the surfaces they encountered.

The possibility that this device is having a negative effect on veliger mortality or downstream settlement may be worth pursuing.

This product was easy to install and maintain and therefore if it can be made more effective by adjustments such as increasing contact time with the magnets, then a useful product may ultimately be developed, however the present design was not effective.

4.7) York Energy - Ion Stick

Zebra mussel colonization of this system was unaffected by this particular product. In all cases incoming veliger densities and colonization densities were very similar to those observed in both control systems.

Although installation was not difficult, the Ion stick, as installed in this study, was not effective in eliminating downstream mussel settlement.

4.8) Modern Concept/NHW Resource Management Ltd. - Hydrodynamics Units

The two products tested from these manufacturers, the 6JR and the 6JR-Z, did not seem to have a direct negative effect on the veligers entering either system, however little or no colonization of the intake line occurred in the case of either product.

It appears that in order for an area to be protected it must be a part of the recirculatory loop. These products were not successful at inhibiting downstream settlement in the holding tank or on the settling plates. It is possible that the continuous flow operation was effecting the ability of mussels to settle which may have added to the effectiveness of the hydrodynamics device. Conversely, continuous flow also exposes the pipe to more veligers and therefore may increase the potential for settlement. The very high veliger densities and settling rate observed in the 6JR system were likely due to the fact that recirculation of water concentrated the veligers in the intake line, thereby increasing the number entering the holding tank. It is not known why the 6JR-Z system did not exhibit this concentrating effect. Simply stated, this design tended to retain veligers in the system without inhibiting downstream settlement.

A number of questions remain with these devices which appear on the surface to have good potential for control of mussels in specific applications. Further research may clarify these questions.

In this study, systems which were protected by the hydrodynamics devices remained relatively mussel free in areas which were part of the recirculation loop. Downstream settlement remains a problem.

4.9) Ron Whitcombe - Zebra Sand Filter

It may be that a land based filter of this type would be useful and this concept should be pursued, however, significant problems exist with the present design of this product.

5.0) CONCLUSIONS

This product evaluation strongly suggests that for the small volume water user, filtration of source water is probably the most reliable, cost efficient, and universally applicable method of preventing zebra mussel colonization of small water user systems. Although higher maintenance was required on most of the filter products due to clogging this would probably be substantially reduced if deployed in a clean shield lake or the relatively clear Kawartha Lakes. The water source at the research site is historically very turbid (NTUs often greater than 9) and this most certainly added to the frequency of maintenance required on the filter products. Clogging problems can also be alleviated by using a greater micron pore size for a pre-filter product. Some of the filters used cartridges with pore sizes as low as 5 microns. Although some other products showed promise (in particular the hydrodynamics units) which may be useful in specific applications, in most cases they would be difficult to install by the average cottage owner, and the data suggests that they are not reliable at inhibiting mussel growth throughout the service water system. Often the exact mechanisms by which they are supposed to work are not well understood.

6.0) SUGGESTIONS/RECOMMENDATIONS

With some modifications, filter products supplied by Lowther Consulting, MYCO Industries and ISP Canada could be used successfully on small volume water systems as protection from mussel infestation. In the case of Lowther Consulting and MYCO Industries, a re-usable and coarser filter cartridge (pre-filter) would definitely be an improvement. In the case of the product from ISP Canada some modifications to allow for installation at the intake end of the pipe need to be made.

A method by which these products could be easily retrievable by the owner would also definitely enhance their performance.

The above mentioned products are singled out due to ease of installation (one person), relative ease of maintenance and overall effectiveness. Other products tested here, in particular the products from Alex Milne Associates Ltd. and the Hydrodynamics Units, may be useful depending on the level of effort or other specific adaption that a water user wishes to employ.

APPENDIX

QUESTIONNAIRE SAMPLE

SMALL WATER USERS QUESTIONNAIRE

1. What body of water do you draw from?

2. Is the water treated in any way?

3. Water use (what is water used for)?

4. Intake diameter (approx.)

5. Intake material

6. Is intake buried or above ground?

7. How far out offshore is the end of the intake and total length of intake?

8. Is it continuous flow or demand only basis?

9. Approximate daily or monthly usage

10. Type of pump used and capacity